MECH 578 Orbital Mechanics and Mission Design

Spring 2021

Instructor: Professor P. Rodi, (Patrick.Rodi@Rice.edu)
Class Hours: Monday/Wednesday/Friday, 6:30pm – 7:25pm, on-line (for now).
Office Hours: Monday/Wednesday/Friday, 4:00pm – 5:00pm, on-line (for now).
Course URL: https://canvas.rice.edu/courses/22331

Course Outcomes Expected:
Students completing the course should be able to:

1. Develop an understanding of orbital mechanics.

2. Obtain a detailed knowledge of the two-body problem and its solutions with applications to geocentric orbits and interplanetary transfers.

3. Understand the concept of impulsive thrusting and its use in orbital transfers including plane changes.

4. Obtain a knowledge of time-of-flight relations on two-body trajectories, using both classical and universal variables.

Textbooks:
1. *Orbital Mechanics* by Chobotov, AIAA Educational Series.
2. *Spacecraft Mission Design* by Brown, AIAA Educational Series.
3. Supplementary material from *Fundamentals of Astrodynamics* by Bate, Meuller and White, Dover, 1st Ed.
4. Supplementary material from *Orbital Mechanics for Engineering Students* by Curtis, Elsevier.

Grading: 25% Mid-Term Examination
30% Mission Planning Project
45% Comprehensive Final Examination

Homeworks: Generally issued weekly, but not required or graded. Solutions will be posted.

Exams: Mid-Term Examination
Comprehensive Final Examination

Please note for Exams:
1. Points will be deducted in your exam if your submission is not clear in logic and presentation.
2. All quantities must have the correct dimensions.
3. All answers must be clearly marked (e.g. boxed or underlined).

Distribution: Engineering science, 3 credits. The course emphasizes theoretical concepts and analysis, and applies mathematical and scientific skills to the problems of predicting spacecraft motion such as when in orbit around a planet, how to change these orbits, how to leave a planet's gravitational influence, how to travel through outer space, and how to be captured by a planet's gravitational field. After an introduction to orbital mechanics, the class will then present an introduction to spacecraft mission planning. This involves time and/or distance phasing to monitor the Earth's surface from orbit or approach and rendezvous with another object (e.g. planet, asteroid, satellite, etc.), and includes launch windows, fly-by missions, and other techniques.

ADA Notice: Any student with a disability requiring accommodations in this course is encouraged to contact the instructor after class or during office hours. Additionally, students should contact Disability Support Services in the Ley Student Center.

Syllabus

1. Basic Concepts
Historical perspective, velocity and acceleration.

2. Celestial Relationships
Coordinate systems, time systems.

3. Keplerian Orbits
Newton's gravitational law, general and restricted two-body problems, conservation of mechanical energy, conservation of angular momentum, orbital parameters of a satellite, orbital elements.

4. Position and Velocity
Universal approach, classical element set, rectangular coordinate system, modified classical to cartesian transformation, rectangular to modified classical elements transformation, spherical coordinate system, rectangular vs. spherical transformations, Earth-Relative-Spherical coordinate system, geodetic and geocentric altitudes.

5. Orbital Maneuvers
Orbital energy, single-impulse maneuvers, single- and two-impulse transfer, Hohmann transfer, bi-elliptic transfer, restricted three-impulse plane change maneuvers, Hohmann transfer with split-plane change, bi-elliptic transfer with split-plane change, transfer between coplanar elliptic orbits

6. Complications to Impulsive Maneuvers
N-Impulse maneuvers, fixed-impulse transfers, finite-duration burns: gravity losses, very low thrust transfers

7. Relative Motion in Orbit
Space rendezvous, terminal rendezvous, application of rendezvous, optimal multiple-impulse rendezvous

8. Introduction to Orbit Perturbations
General overview, Earth gravity harmonics, lunisolar gravitational attractions, radiation pressure effects, atmospheric drag, tidal forces, mutual gravitational attractions

9. Observing the Central Body
Effect of the launch site, orbit perturbations, grand track, spacecraft horizon, constellations

10. Special Earth Orbits
Geosynchronous orbit, sun-synchronous orbit, Molniya orbit, low Earth orbit

11. Lunar Trajectories
Motion of the Earth-Moon system, time of light and injection velocity, sphere of influence, lunar patched conic

12. Interplanetary Trajectories
Patched conic approximations, patched conic procedure, locating the planets, design of transfer ellipse, design of departure trajectory, design of arrival trajectory, gravity-assist maneuver, cycler orbits, establishing planetary orbit